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MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE IN THE 0.7- TO 2.8-M--ETC(U)

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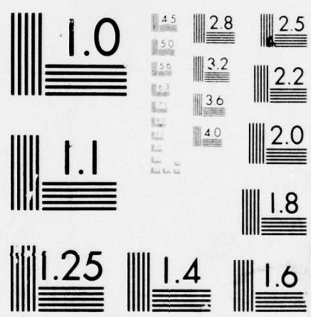
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
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MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE IN THE 0.7- TO 2.8-MICROMETER INFRARED REGION

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May 1977

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MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE
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Page 2, second paragraph on page, eighth line in paragraph

Change "The combined electronics and noise level..." to "The combined electronics noise level..."

Page 4, first full paragraph, seventh line from bottom of paragraph

Change 1630 MST to 1636 MST

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The objective of this experiment was to measure atmospheric irradiance within the 0.7- to 2.8-micrometer infrared wavelength region from a balloon platform at altitudes ranging from 5 to 39 kilometers. An Epply precision spectral pyranometer pointed in a general downward direction and equipped with a 7-degree field of view field stop was successfully employed to collect irradiance data for a period of 34 hours on 23, 24, and 25 September 1976. The results showed that at low solar zenith angles and in the absence of clouds the atmospheric

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1/100 cal/sq cm

20. ABSTRACT (cont)

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irradiance values usually remained within 2.2 x 10^{-2} cal/cm^2 min and 2.6 x 10^{-2} cal/cm^2 min. Clouds attenuated the irradiance down to magnitudes below 4 x 10^{-4} cal/cm^2 min which was the combined noise level of the pyranometer and associated electronics. At high solar zenith angles, specular reflections of sunlight which entered the pyranometer's field view caused enhancements of the measured irradiance to reach magnitudes greater than the instrument could measure (3.5 x 10^{-2} cal/cm^2 min). No significant variations in irradiance were detected with changes in altitude above 5 kilometers or terrain viewed; therefore, the background intensity is attributed to the radiant emittance of the lower atmosphere.

1/10000 cal/sq cm

CONTENTS

INTRODUCTION

The existence and causes of naturally occurring atmospheric infrared light emission with intensity magnitudes greater than those of the normal background have been important to the military services since the advent of remote sensing reconnaissance and surveillance systems. To supplement existent, but insufficient, data on atmospheric near infrared light emission or reflections, the experiment to be described in this report was designed as part of project STRATCOM VI-A. STRATCOM VI-A was a high-altitude balloon project consisting of a multi-instrument atmospheric-sensing payload designed to make simultaneous measurements of solar and atmospheric radiation, atmospheric composition, and the thermodynamic structure in the 5- to 40-kilometer altitude interval. The specific objective of this particular STRATCOM VI-A experiment was to acquire atmospheric irradiance data within the 0.7- to 2.8-micrometer wavelength region and to attempt to identify the cause of any intensity enhancements detected during the balloon flight.

INSTRUMENTATION

An Epply precision spectral pyranometer with an RG8 light filter (0.7- to 2.8-micrometer window) was used to measure atmospheric irradiance. A field stop machined to limit the field of view to 7 degrees was attached to the pyranometer. Inclusion of the field stop reduced the pyranometer sensitivity to 0.38 millivolt/(cal/cm^2 min). Thus to provide a voltage signal sufficiently large to telemeter, the sensor output was amplified by two cascaded operational amplifiers enclosed in a temperature controlled container. The combined electronics and noise level was measured to be 0.1 microvolt; this value is equivalent to an irradiance level of 4×10^{-4} cal/cm^2 min. Based on previous data [1] rounded off to the next higher order of magnitude, the Epply pyranometer sensitivity and its viewing solid angle of 0.01 steradian, the maximum anticipated irradiance level was calculated to be 3×10^{-2} cal/cm^2 min. This corresponds to an equivalent pyranometer output voltage of approximately 10 microvolts. Accordingly, the total gain of the operational amplifiers was set to accentuate the sensor output voltages between 0.1 and 10 microvolts. Because of the high amplifier gain employed, sensor output voltages above 13.3 microvolts saturated the modulation signal; therefore, all irradiance data which produced a sensor output voltage larger than 13.3 microvolts were electronically limited to the corresponding value of 3.5×10^{-2} cal/cm^2 min.

The pyranometer and its appendage were located at the bottom side of the balloon's instrumentation platform. Its optical axis pointed toward the earth at an angle of 17.6 degrees below the horizontal plane defined by the platform base. All irradiance data were recorded after the payload platform had been lowered 300 meters below the balloon.

IRRADIANCE DATA

Net atmospheric irradiance data were intermittently recorded for a period of approximately 34 hours. During balloon ascension, the pyranometer sensed slanted atmospheric path lengths ranging from 17.5 to 130 kilometers. The first data sample (Fig. 1(a), 2312 MST), recorded at an altitude of 5.3 kilometers, corresponds to the 17.5-kilometer slant path; while the eighth data sample (Fig. 1(b), 0230 MST), recorded at an altitude of 39 kilometers, corresponds to the 130-kilometer path. During this balloon climb phase, the irradiance background magnitudes did not vary as a function of the observed path length, as can be seen in Figs. 1(a) and 1(b). This is attributed to the fact that when the initial data sample was obtained, the pyranometer was already sensing a large majority of the air mass and most of the precipitable water vapor, both of which were located in the region of the atmosphere with the highest temperature where the bulk of the atmosphere's radiant emittance occurs. Other than the third data sample, obtained at 0005 MST, 24 September, the irradiance remained within 2.3×10^{-2} cal/cm^2 min and 2.6×10^{-2} cal/cm^2 min. The abrupt decrease in intensity to less than 4×10^{-4} cal/cm^2 min recorded at 0005 MST was probably produced by cloud attenuation of the low-altitude atmospheric radiance. However, due to the lack of precise information on cloud locations at 0005, it cannot be unequivocally stated that a cloud obscured the pyranometer's field of view.

Investigation of the balloon's projected ground trajectory and the type of earth surface terrain traversed by this trajectory revealed that variations in the recorded irradiances were uncorrelated to changes in the type of observed terrain. Observed terrains consisted of flat desert, semibarren mountains, forrested mountains and valleys, and small lakes. Calculation of the earth's radiant emittance, at a temperature of 25°C, and unity emissivity, within the 0.7- to 2.8-micrometer region, yielded an irradiance value of 1.5×10^{-4} cal/cm^2 min. This intensity is below the operating signal threshold of the instrumentation employed here. Thus the small changes in irradiance brought about by changes in terrain temperatures and emissivities went undetected.

Measurements recorded during the balloon's first float altitude of approximately 39 kilometers covered the time interval from 0256 MST to 1142 MST, 25 September. Within this time span, the atmosphere was sensed during night, sunrise, and daylight hours. The recorded data are shown in Figs. 1(c), 1(d), and 1(e). Irradiance levels generally remained between 2.3×10^{-2} cal/cm^2 min and 2.6×10^{-2} cal/cm^2 min without any noticeable variations during sunrise. Orientation of the pyranometer's field of view was such that it never faced the sun directly. The intensity enhancement expected at sunrise was that due to the clear sky atmospheric scattering of the near infrared light. However, a post-flight computation based on the data of [1] indicated that the additional

irradiance due to clear sky atmospheric scattering of 0.7 to 2.8 micrometers energy was 3×10^{-4} cal/cm^2 min or less, clearly a magnitude less than the instrument's noise level. The gradual decreases in intensity registered at 0330 MST and 0451 MST are attributed to the attenuation effects of clouds entering the pyranometer's field of view. While the sky on the morning of 24 September may be described as generally clear (less than 0.1 coverage), the afternoon was characterized by increased cloudiness which intermittently obscured the pyranometer's field of view.

In the time frame from 1030 MST to approximately 1850, eight irradiance data samples were acquired while the balloon descended from 38 to 27.4 kilometers. The last of these samples was 2 hours long so that not only this experiment but also other STRATCOM experiments would record continuous data during sunset. The irradiance amplitudes did not change appreciably during sunset. All the variations observed were comparable to the small changes already recorded throughout most of the flight when the amplitudes were centered about 2.4×10^{-2} cal/cm^2 min. In contrast, before sunset, beginning at 1631 MST large variations in irradiance levels were observed. Because of the increased cloudiness on this afternoon and with the sun's attainment of a high zenith angle, cloud specular reflection of sunlight entered the pyranometer's field of view and enhanced the irradiance amplitudes to values greater than 3.5×10^{-2} cal/cm^2 min. These enhancements are shown in Figs. 1(f) and 1(g). As previously mentioned, values greater than 3.5×10^{-2} cal/cm^2 min are not plotted because the electronics became saturated at this magnitude. Consequently, it may be stated only that the values registered at 1630 MST and 1821 MST were greater than 3.5×10^{-2} cal/cm^2 min. Since preflight calculations of solar energy scattering (diffused light) of 0.7 to 2.8 micrometers light from sunlit clouds yielded a maximum irradiance of only 3×10^{-2} cal/cm^2 min, it is maintained that the enhancements recorded at 1630 MST and 1821 are indeed specular cloud reflections. When clouds were in the pyranometer's field of view, the balloon platform's slow motion caused the pyranometer to sense in sequence either solar specular reflections or atmospheric irradiance attenuated by the same clouds. This process effectively introduced the irradiance fluctuations recorded in Figs. 1(f) and 1(g). At sunset all enhancements ceased.

During the remainder of the balloon flight, eight more samples were obtained as the balloon rose to 39 kilometers. Most of these data, plotted in Figs. 1(h), 1(i), and 1(j) were recorded at night. Other than the decreases in irradiance recorded at 2004 MST and 2114 MST on 24 September and at 0550 MST on 25 September, the intensity levels did not significantly deviate from 2.5×10^{-2} cal/cm^2 min. Sunrise effects were again found to be negligible. All values recorded after 0558 MST, last data point in Fig. 1(j), also remained close to a value of 2.5 $\times 10^{-2}$ cal/cm^2 min.

CONCLUSIONS

Net lower atmosphere 0.7- to 2.8-micrometer irradiance data were successfully recorded for a period of 34 hours from altitudes ranging from 5.3 to 39 kilometers. An irradiance background level which usually remained between 2.3×10^{-2} cal/cm^2 min and 2.6×10^{-2} cal/cm^2 min existed during both day and night. This irradiance level is in general agreement with data reported by K. YA. Kondratyev [2] when only that fraction of energy due to the near infrared is obtained from Kondratyev's total irradiance. Since no appreciable variations in irradiance with increases in altitude were observed between 5.3 and 39 kilometers, it is concluded that the aforementioned irradiance levels are maintained by air mass in the lower atmosphere. Changes in the radiant emittance of the earth's surface terrain were too small to be detectable. Clouds entering the sensor's field of view acted as attenuators of the lower atmosphere irradiance. More importantly, it was established that the existence of clouds located in a position to specularly reflect sunlight into a sensor can cause intensity enhancement well above the background irradiance.

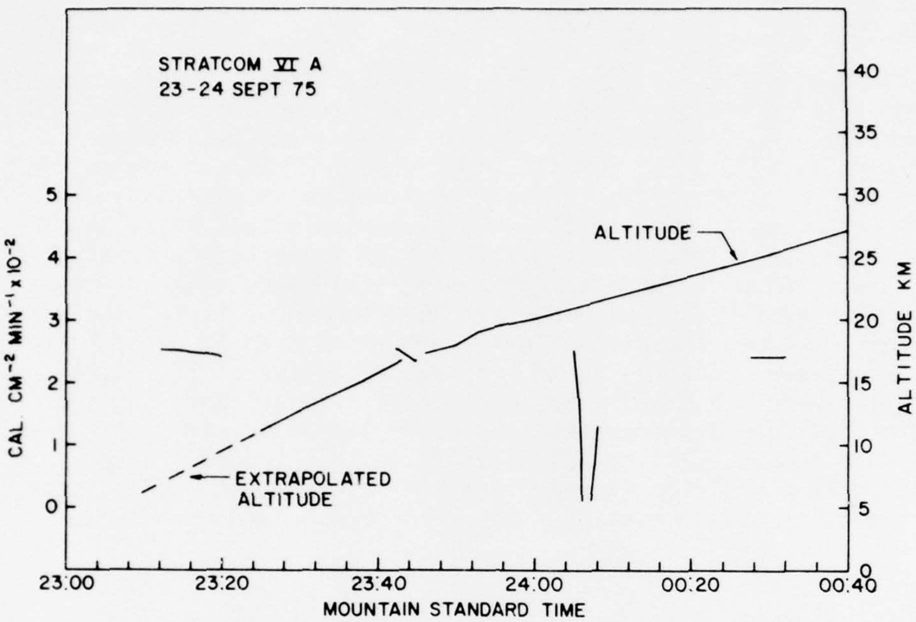

FIGURE 1 (a) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

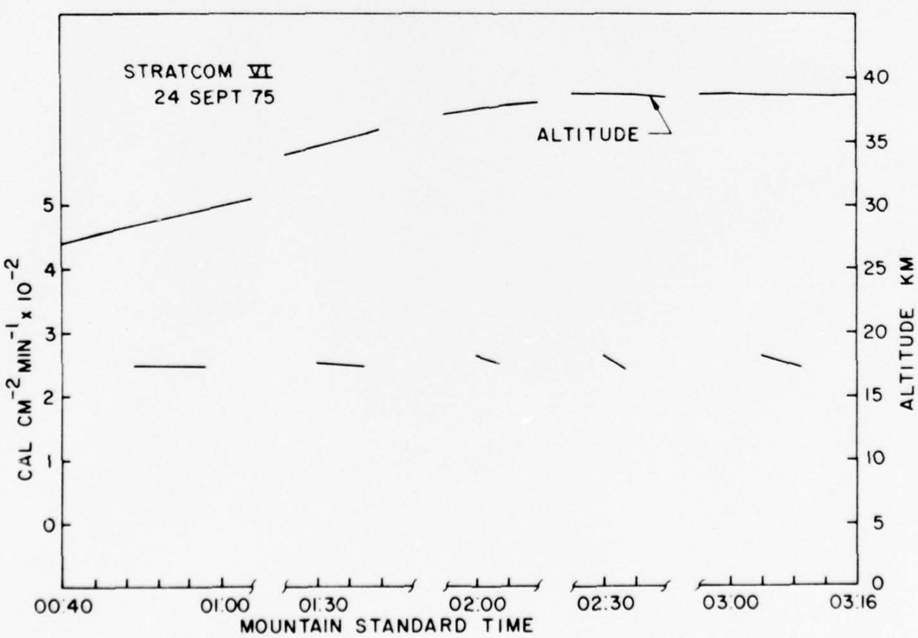

FIGURE 1 (b) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

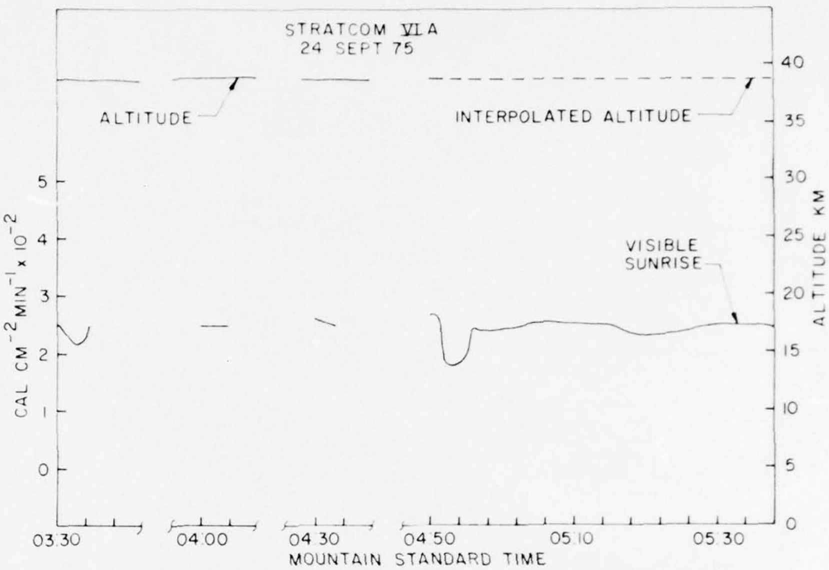

FIGURE 1 (c) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

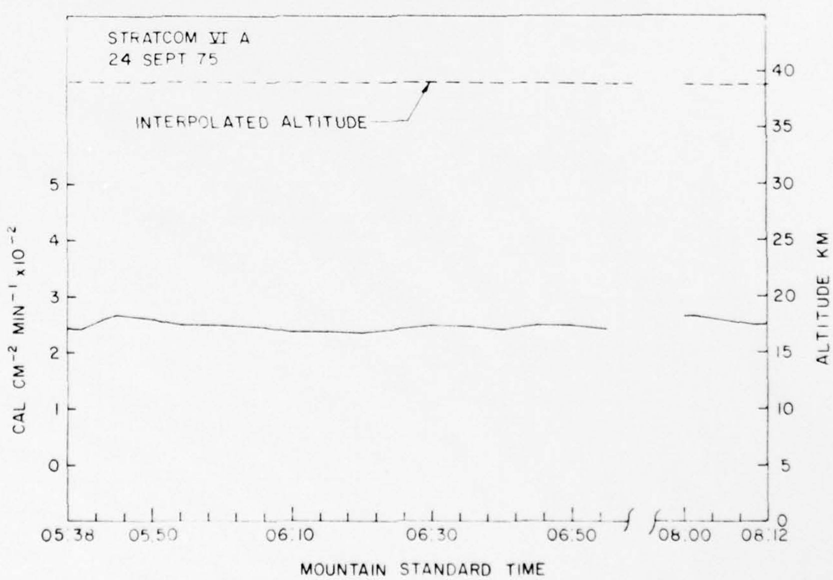

FIGURE 1 (d) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

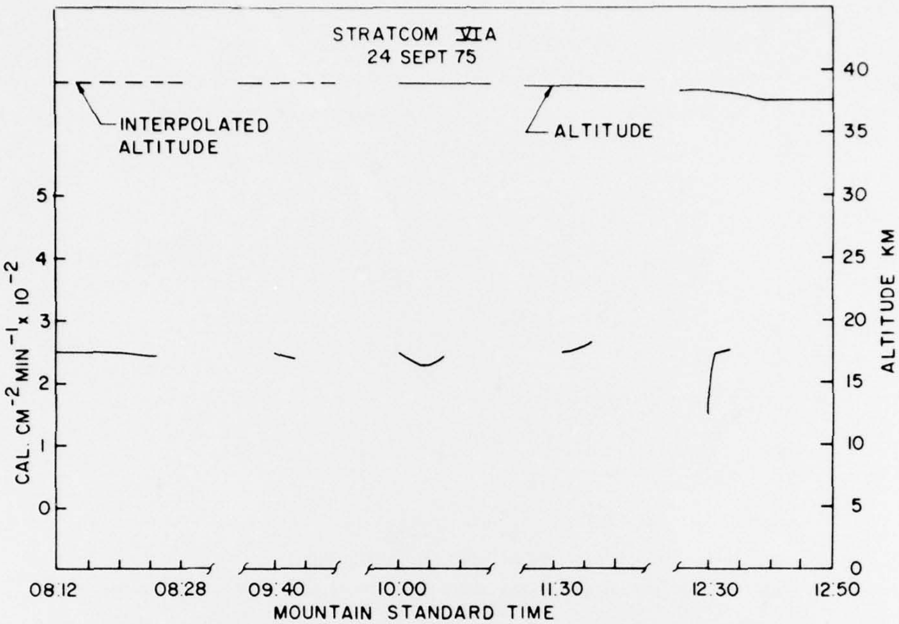

FIGURE 1 (e) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

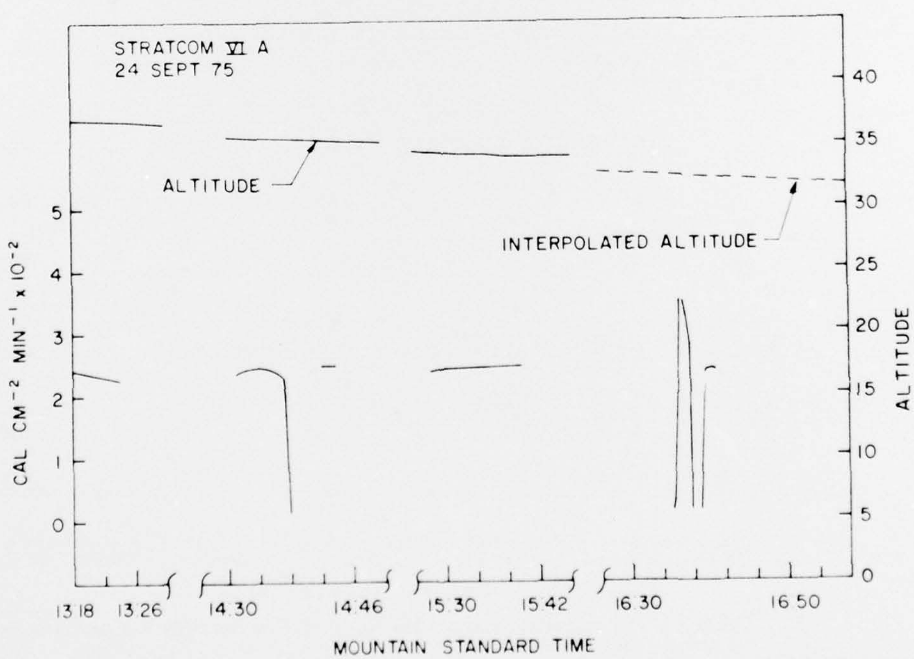

FIGURE 1 (f) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

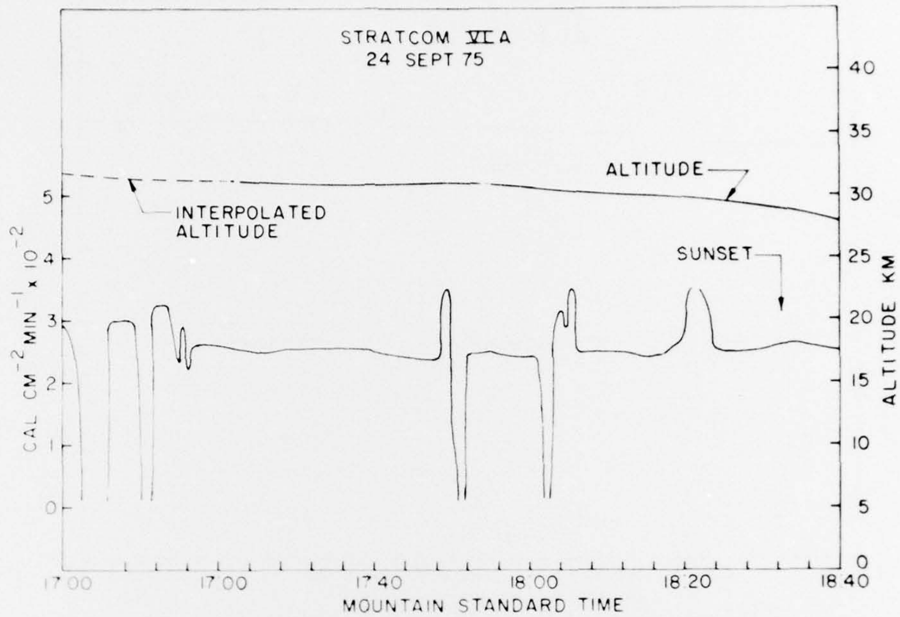

FIGURE 1 (g) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION AND ALTITUDE

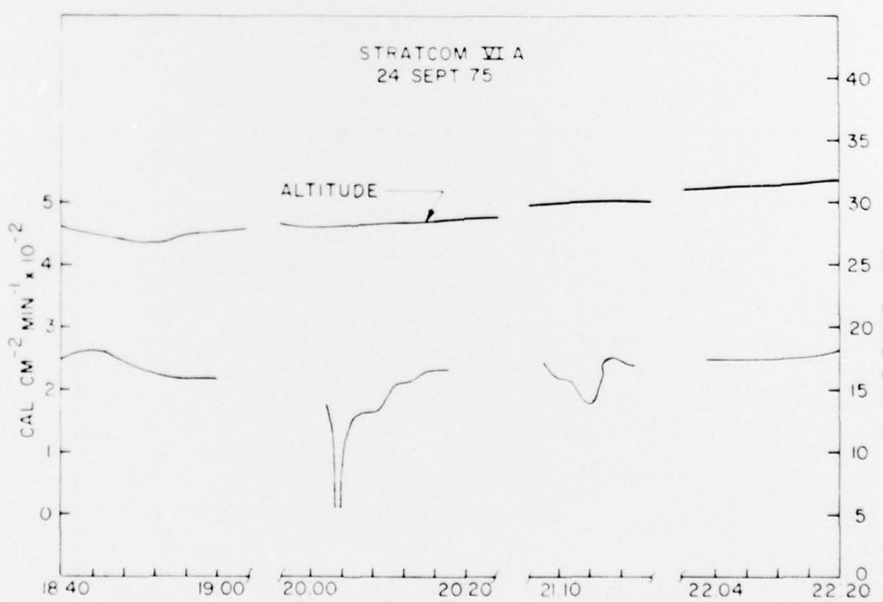

FIGURE 1 (h) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

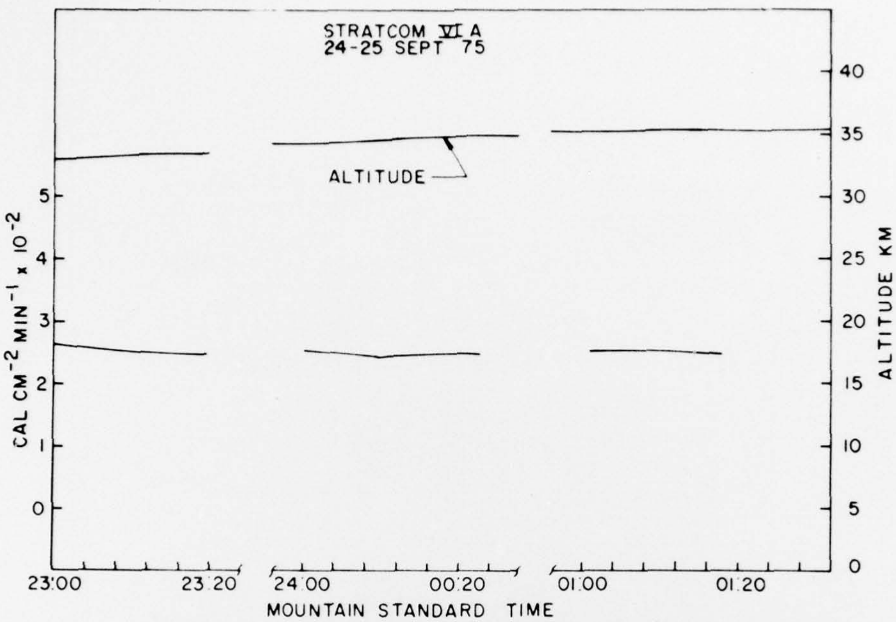

FIGURE 1 (i) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

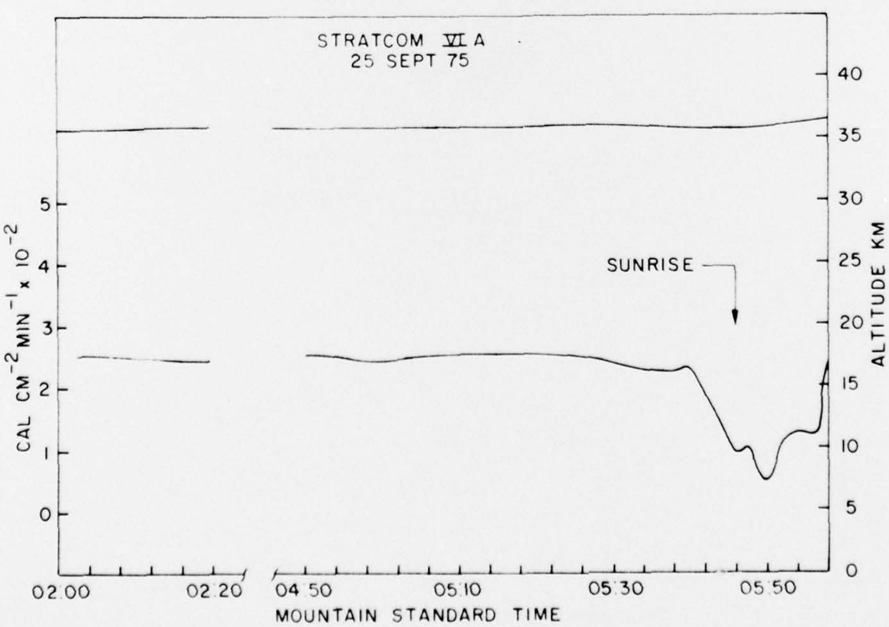

FIGURE 1 (j) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

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